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STRUCTURE AND STRATIGRAPHY OF SARHOTA, BANI NAGAL, DUNGI AND THIL AREAS OF DISTRICT KOTLI, JAMMU AND AZAD KASHMIR

S. IQBAL, *N. AADIL and S. PARVEZ[1]

Department of Geological Engineering, University of Engineering and Technology, Lahore, Pakistan

[1]Institute of Geology, University of Azad Jammu & Kashmir, Muzaffarabad, A.J.K

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The study area lies in the adjoining areas of the District Kotli, Azad Kashmir which lies along the eastern limb of the Hazara-Kashmir Syntaxis in the sub-Himalaya of Pakistan. This is a part of Kashmir fold and thrust belt which is formed after the collision of the Indian and Eurasian plates. The lithostructural mapping of Sarhota, Bani Nagala, Dungi and Thill areas is carried out. The lithostratigraphic units exposed are Hangu of Early Paleocene, Patala of Late Paleocene, Margalla Hill Limestone of Early Eocene, Chorgali of Early Eocene, Kuldana of Late Eocene, Murree of Early Miocene, Chinji, Nagri, Dhok Pathan, Soan of Middle to Late Miocene, Mirpur of Pliocene Formations of and Recent Alluvium of Pleistocene. Structurally, the area is highly deformed. Different folds and faults are mapped. The Gawan syncline, Gawan anticline, Sarda-Sarhota syncline, Mandi syncline and Fagosh anticline are the major folds developed in the area. These are tight to open folds which extend northwest to southeast direction. Different parasitic folds along the limbs of the major folds are developed in the study area. The Riasi Fault or Himalayan Frontal Thrust and Fagosh Fault are two major faults present in the study area. The Riasi Fault separates the Early Miocene Murree Formation and Late Miocene Dhok Pathan Formation. The Fagosh Fault is an intraformational fault which lies in the core of Fagosh anticline. Primary sedimentary structures such as cross bedding, ripple marks, load casts and rip ups are used in determining the facing of the stratigraphic units.

Keywords: Kotli, Azad Kashmir, Hazara-Kashmir syntaxis, Lithostructural mapping, Primary and secondary structures, Facing

1. Introduction

The study area of about 54 Km^2 lies in the Kotli district of Azad Kashmir along the eastern limb of the Hazara-Kashmir Syntaxis (HKS). The area is located between 33°22′ to 33°30′ N and 73°57′30″ to 74°00′E and lies on topographic Sheet No. 43 G/15 of Survey of Pakistan (Figure I). Himalayan Frontal Thrust bound the area to the east, Salt Range Thrust to the south and to the north and northwest Main Boundary Thrust bound it. Tectonically the area lies in Sub Himalayas in the Kashmir Basin.

The regional stratigraphic study and geological maps were carried out by different workers [1-6]. They suggested that the rocks were derived from the crystalline and sedimentary rocks of lesser Himalayas in the Pir Punjal ranges; however, they did not work on the structure of the area. Recently, Aadil and Rehman [7] presented work on adjoining area with similar objectives but did not cover the study area. Therefore, the present study is focused on the detailed geological and structural mapping of the area with following main objectives:

- Preparation of geological map of 54km^2 area on scale 1:50,000
- Preparation of structural map.
- Preparation of structural cross-sections.
- Preparation of β and π diagrams for structural analysis of the area.

2. Methodology

A field work of 30 days was completed on traverses along and across the bedding planes of the rock units. The Brunton compass was used to map the area to record the attitude of the bedding planes. The photographs of important features were also taken. The sedimentary structures in the field were used to determine the top and bottom of the different stratigraphic units. The acquired structural data were plotted on the structural maps and stereograms. The traverse route map (Figure 1), geological & structural maps (Figure 2) and structural cross sections (Figure 3) of the study area are prepared.

3. Stratigraphy

The mapped geology of the area is shown in Table I which shows that sedimentary rocks of Paleocene to Recent age are exposed in Kotli area. Paleocene-Eocene rocks such as Hangu, Patala, Margalla Hill Limestone

* Corresponding author : naseemaadil@gmail.com

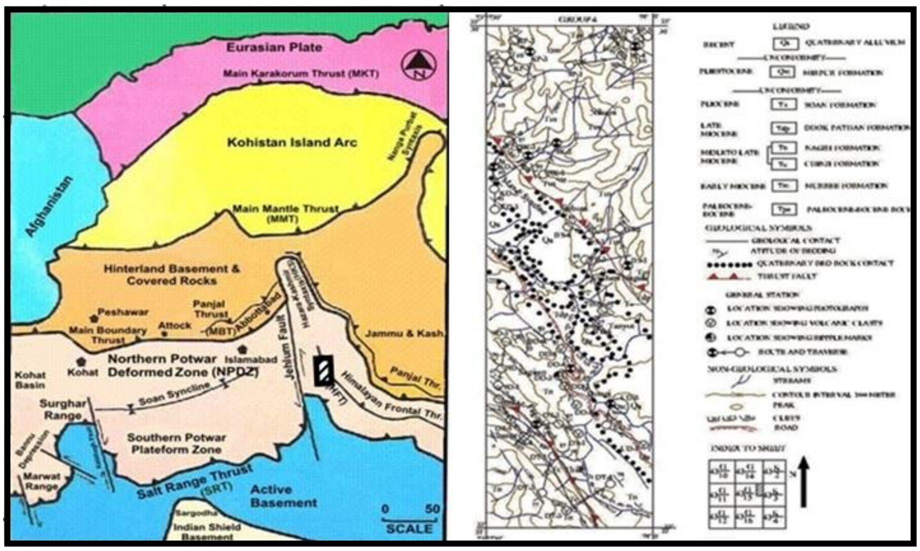

Figure 1. Regional tectonic map of the Northwest Himalayas of Pakistan with location map and traverse route map of the study area.

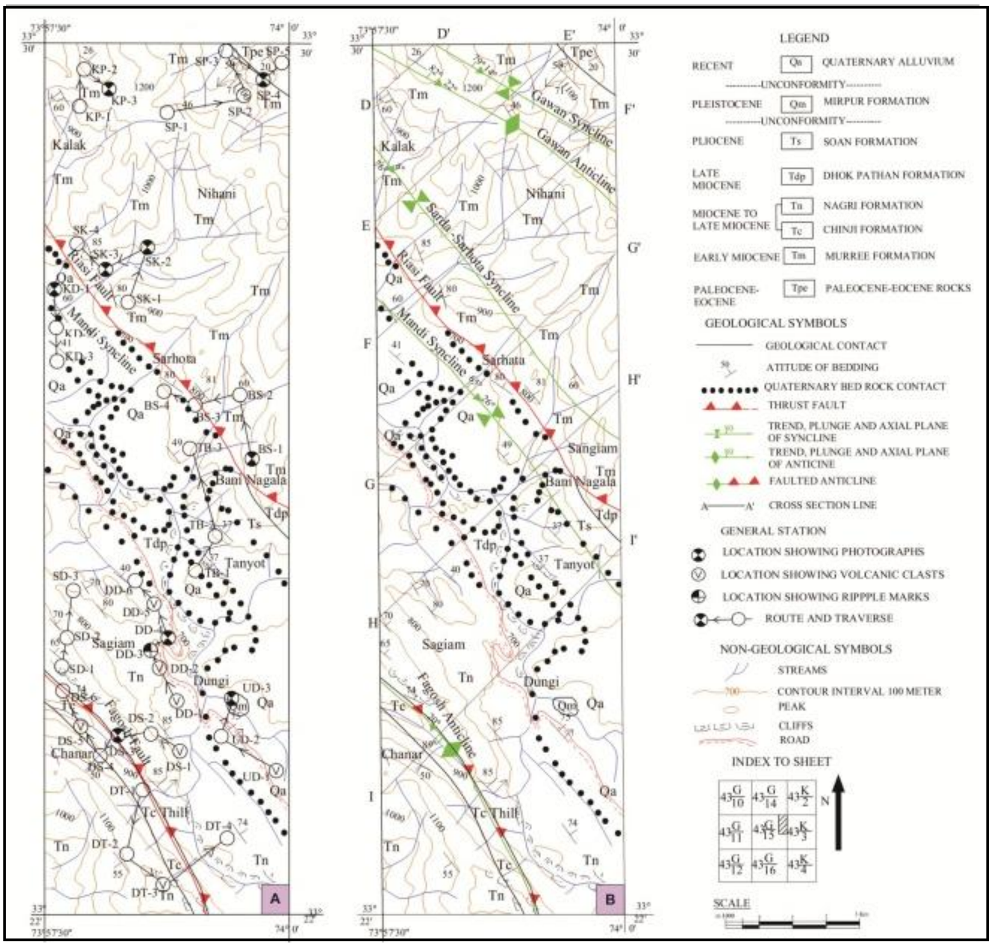

Figure 2. Geological and structural maps of the study area along with traverses.

Table 1. Stratigraphy of the area; the shaded lithological units are only exposed in the studied area.

Alluvium	Recent	Unconsolidated deposits of clay, silt and gravel.
Unconformity		
Mirpur Formation	Pleistocene	Poorly sorted conglomerates consisting of pebbles, cobbles of igneous, sedimentary and metamorphic rocks and clayey matrix.
Unconformity		
Soan Formation	Pliocene	Bentonite clays and conglomerates consisting of fragments of cherty dolomite, Punjal volcanic, granite gneisses, basic dikes/sills and quartzite veins and compact arenaceous matrix.
Dhok Pathan Formation	Late Miocene	Grey, fine to medium grained, medium to thick bedded sandstone with clay and siltstone. Sandstone 60%and clays 40%.
Nagri Formation	Late Miocene	Greenish grey to light grey, massive medium to coarse gained sandstone, siltstone and mudstone. The sandstone alternate with clays. The clays are 30-40% and the sandstone is 60-70%.
Chinji Formation	Middle to Late Miocene	Red to purple, greenish grey, ash grey sandstone and siltstone, purple and reddish brown mudstone. Clays are 50-60% and sandstone is 40-50%.
Murree Formation	Early Miocene	Clays, shales and sandstone. Sandstone is fine to medium grained, reddish and grey.
Kuldana Formation	Late Eocene	Sandstone, shales, subordinate limestone and mudstone. Maroon color sandstone composed of sand and clay.
Chorgali Formation	Early Eocene	Shales and dolomitic limestone. Shales are calcareous. The color shales is grey to greenish color
Margalla Hill Limestone	Early Eocene	Nodular limestone and subordinate. Shales are highly fossiliferrous.
Patala Formation	Late Paleocene	Shales, marl and subordinate limestone. Shales are of khaki color.
Hangu Formation	Early Paleocene	Laterite, bauxite and fireclay
Unconformity		
Muzaffarabad Formation	Cambrian	Dolomitic limestone, cherty dolomite and chert bands.
Unconformity		
Dogra Formation	Precambrian	Slates
Precambrian Basement rocks		

and Chorgali Formations are not the mapable as individual units on the 1:50000 scale. Therefore, they are mapped collectively as Paleocene-Eocene rocks. Murree Formation of Miocene age is the oldest rock unit exposed in the area. Above Murree Formation the Siwalik Group (Chinji, Nagri, Dhok Pathan and Soan Formations) of late Miocene to Pleistocene age is exposed, however the Kamlial unit is missing (Table 1). In the study area the lithological units are classified and described as under:

Murree Formation is well exposed in Bani Nagala, Dasia, Nihani, Dhanna Karhali, Mora and Kalak areas (Figure 3A). In HKS and adjacent areas, Murree Formation is named to the cyclic sequence of sandstones and shales with claystone by Ashraf et al. [4] and Ghazanfar et al. [9]. Murree Formation consists of well bedded sandstone, shales, grits and subordinate siltstone [10]. The Murree Formation is the oldest formation of the molasse deposits.

In the lower part of the formation fine to medium grained ferruginous sandstone is compact, hard and fractured at places. Its weathered color is reddish brown and fresh color is light grey (Figure 3A). The sandstone of upper part is thickly bedded and massive which is composed of quartz, feldspar, muscovite and clay particles. The color of shales is red and maroon. The

Figure 3. Field photographs showing (A) Murre Sandstone near Sarhota, Spheroidal weathering near Danna in Sandstone, (B) Nagri Formation and (C) Dhok Pathan Formation, (D) Angular contact Between Mirpur Formation-A and underlying Soan Formation-B, (E) Riasi Fault between Murree and Dhok Pathan Formations near Sarhota and finally (F) Shearing and crushing in Chinji Formation in the core of Fagosh anticline along Fagosh Fault. Arrows indicate the north direction.

formation is highly fractured and folded along the Riasi fault. The lower contact of the Murree Formation is gradational with Kuldana Formation and upper contact with Dhok Pathan Formation is faulted. This Formation has no record of fossils except some petrified wood plants remains. The age of the Murree Formation is Early Miocene [9, 11].

Siwalik Group is the upper part of molasse deposits and is mainly consists of brick red clays, sandstone and conglomerates. The ratio of sandstone and clays varies in different rock units. Siwalik deposits in the area were divided in four lithostratigraphic units as: Chinji; Nagri; Dhok Pathan and Soan Formations having gradational contacts based on faunal occurrence.

Chinji Formation is mainly exposed at Dheri, Saplan and Thill areas (Figure 3B). Lithologically the Formation consists of brick red color clays, ash grey to brownish grey sandstone and grits. The sandstone is well bedded, fine to medium grained, cross bedded and soft. It is hard at basal part of the Chinji Formation. Clay and sandstone ratio is 60:40. Intraformational conglomerates are also found in Chinji Formation. It is separated from Nagri Formation on the basis of occurrence of volcanic clasts and sandstone clay ratio. The upper contact of Chinji Formation is gradational with Nagri Formation while lower contact with Kamlial Formation is absent in the project area. The age of the Chinji Formation is Late Miocene [10].

Nagri Formation is a thick sequence of sandstone of Late Miocene age [10] which is distributed at Danna, Pailan Sagiam, Dungi, Chiran, Saplan and Thill areas. The Nagri Formation consists of sandstone with subordinate conglomerates and clays. Different grit levels are also observed at places. The sandstone is compact, hard, coarse grained, cross bedded, jointed and fractured. The color of sandstone is greyish brown. The shale is yellowish, reddish and blackish. The conglomeratic layers present in the formation having pebbles and gravels of older rocks like Punjal Volcanic, quartzite, sandstone and limestone. The Nagri Formation has a specific character of spheroidal weathering and salt and pepper texture (Figure 4C). Ripple marks are also observed on the bedding surfaces at places. The upper contact of Nagri Formation is transitional with overlaying Dhok Pathan Formation and lower contact is also transitional with underlying Chinji Formation.

Dhok Pathan of Late Pliocene age [10] is exposed at Sarhota, Dasia, Kingrian, Faizabad and Numb Danna (Figure 3C) and mainly consists of equal ratio of sandstone and shales which show the cyclic deposition. The sandstone is 60% and the clays are 40% [7]. The sandstone is medium to thick bedded, cross bedded, jointed, fractured and less compacted than Nagri Formation. The sandstone is coarse grained having rounded to angular grains of quartz, muscovite, biotite, feldspar, epidote, tourmaline and pink garnet respectively. The upper and lower contact of the Dhok Pathan Formation is transitional with Soan and Nagri Formations respectively. The Dhok Pathan Formation is highly fossiliferrous having vertebrate fossils.

Soan Formation of Pliocene age [10] is exposed at Sarhota and Kartot areas and mainly consists of conglomerates with subordinate lenses of sandstone, siltstone and clay. The conglomerates are mainly composed of rounded to sub rounded pebbles and boulders of different sizes. The size of clasts ranges from 1cm to 20cm. The conglomerates are of Murree sandstone, Paleocene-Eocene limestone, Punjal Volcanics, granite gneisses and quartzites. The matrix in the conglomerates is medium to coarse sand and calcite. The conglomerates of Soan Formation are differentiated from the conglomerates of Mirpur Formation on the bases of nature of matrix. The upper contact marks an angular unconformity with overlying Mirpur Formation and lower contact is transitional with Dhok Pathan Formation but at Kartot area it has faulted contact with Murree Formation (Plates 2a, and 3a). The Soan Formation is exposed in the core of the Mandi Syncline.

Mirpur Formation of Pleistocene age is exposed at Kotli, Mirpur area which is equivalent to Lei conglomerate in Potwar area. The name Mirpur Formation is introduced by Geological Survey of Pakistan [1]. The Mirpur Formation is exposed at Sarhota, Samror and Dungi along the stream. The formation consists of conglomerates, and lenses of sandstone. The conglomerates have the boulders and pebbles of Punjal Volcanics, Murree sandstone, quartzites, granite gneisses and limestone. They are less compacted and loose than Soan Formation. The Mirpur formation has angular contact with the underlying Soan Formation (Figure 3D).

Quaternary Alluvium deposits are exposed in the artot, Alkar, Samror, Kingrian, Faizabad and Numb Danna areas. These are recent river alluvium deposits in terrace forms and consist of horizontally bedded clays, sands and gravels. The alluvium in the area is loose sand, silt and clay having yellowish to grey color. The terraces are used for agricultural purposes.

3.1. Structure

The study area is the part of the Kashmir fold and thrust belt and lies along the southeastern limb of the Hazara-Kashmir Syntaxis. The Himalayan mountain belt is divided into higher, lesser and sub-Himalayas by five major thrusts i.e. Himalayan Frontal Thrust (Kashmir Boundary Thrust), Main Boundary Thrust, Main Central Thrust and Indus Tsangpo Suture Zone [12]. The Himalayan Frontal Thrust extends to Kotli area which is between the Murree Formation and the Siwalik Group of rocks.

3.2. Folds

In the study area, the rocks are highly deformed into large scale folds and faults due to Himalayan uplifting. The major structures developed in the area are Gawan Syncline and Anticline, Sarda – Sarhota syncline, Mandi Syncline and Fagosh Anticline.

3.3. Gawan Syncline and Anticline

The Gawan syncline lies in the northeastern part of the study area. The syncline is formed by the folding of the Paleocene-Eocene rocks sequence and the Murree Formation. The Murree Formation is in the core whereas the Paleocene-Eocene rocks lie on the limbs of the Gawan syncline as shown in cross sections AA′, BB′, CC′ (Figure 4). The northeastern limb of the syncline dips towards the southwest whereas the southwestern limb dips in the northeast. The strike of the northeastern limb is N42˚W whereas the strike of the southwestern limb is N29˚W. The dip of the northeastern limb is 71˚SW whereas the dip of the southwestern limb is 46˚NE (Table 2; Figure 5, β_1). The northeastern limb is relatively steeper than the southwestern limb. The trend and plunge of the fold axis is 14˚/138˚. The strike of the axial plane is N36˚W and dip is 79˚NE. The interlimb angle of the syncline is 63˚ (Table 2; Figure 5, β_1). On the basis of interlimb angle the fold is classified as an open fold. The Gawan syncline is a plunging southwest verging fold.

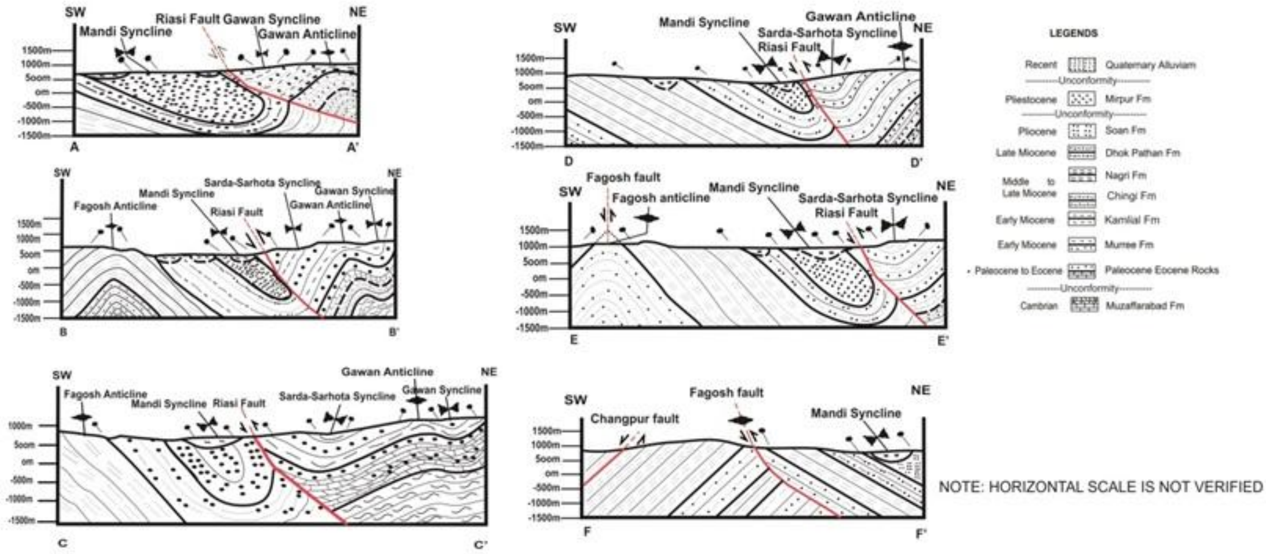

Figure 4. Structural cross sections of Sarhota, Nihani and Sangiam areas of district Kotli, Azad Jammu & Kashmir.

The Gawan anticline is formed by the folding of Paleocene-Eocene rock sequence and Murree formation. The Paleocene-Eocene rocks sequence is present in the core whereas Murree Formation lies on the limbs of the fold. The anticline extends in northwest-southeast direction and shares its southwestern limb with Sarda-Sarhota syncline and northeastern limb with Gawan syncline. The northeastern limb dips in northeast whereas the southwestern limb dips in the southwest as shown in cross sections AA′, BB′, CC′ (Figure 4). The strike of the northeastern limb is N29˚W and dip is 46˚NE. The strike of the southwestern limb is N58˚W and dip is 60˚SW. The southwestern limb is relatively steeper than the northeastern limb. The plunge and trend of the fold is 22˚/129˚. The attitude of the axial plane is N50˚W/82˚NE. The interlimb angle of the anticline is 74˚ (Table 2; Figure 5, β_2). On the basis of interlimb angle the fold is classified as an open fold. The Gawan anticline is a southeast plunging and southwest verging fold.

3.4. *Sarda-Sarhota Syncline*

The Sarda-Sarhota syncline extends in northwest-southeast direction within the Murree Formation. The syncline is formed due to the folding of the Murree Formation and the Paleocene-Eocene rocks. The Murree Formation is in the core whereas the Paleocene-Eocene rocks lie on the limbs of the syncline. The southwestern limb of the syncline is cut by the Riasi Fault as shown in cross sections BB′, CC′, DD′, and EE′ (Figure 4). The strike of the northeastern limb is N27˚W where as the strike of the southwestern limb is N20˚W. The dip of the northeastern limb is 60˚SW and the dip of the southwestern limb is 85˚NE. The plunge and trend of the fold axis is 06˚/158˚. The attitude of the axial plane is N22˚W / 76˚SW (Table 2; Figure 5, β_3). The interlimb angle of the syncline is 35˚. The interlimb angle shows that the Sarda-Sarhota syncline is a close fold. The Sarda-Sarhota syncline is a plunging and northeast verging fold.

3.5. *Mandi Syncline*

The Mandi syncline is formed by the folding of the Nagri Formation, Dhok Pathan Formation and Soan Formation. The Soan Formation is in the core of the syncline. The Dhok Pathan and the Nagri Formation lies on the limbs of the syncline. The northwestern limb of the syncline is cut by the Riasi Fault as shown in cross sections CC′, DD′, EE′, and FF′ (Figure 3). The Mandi syncline extends in northwest-southeast direction. Both limbs of the syncline dip towards the northeast. The strike of the northeastern limb is N58˚W and the strike of the southwestern limb is N38˚W. The dip of the northeastern limb is 80˚ NE whereas the dip of the southwestern limb is 49˚ NE. The northeastern limb is relatively steeper than the southwestern limb. The attitude of the axial plane is N50˚W /65˚NE. The trend and plunge of the fold is 26˚/ 132˚ and the interlimb angle is 31˚ (Table 2; Figure 5, β_4). On the basis of interlimb angle the fold is classified as close fold. The Mandi syncline is a plunging and northeast verging fold.

3.6 *Fagosh Anticline*

The Fagosh anticline is formed by the folding of the Chinji Formation and the Nagri Formation. The Chinji Formation lies in the core and the Nagri Formation on the limbs of the anticline. The Fagosh anticline is a faulted anticline. Core is faulted due to the Fagosh Fault

Table 2. Structural data of Gawan syncline and anticline, Sarda-Sarhota syncline, Fagosh anticline.

Structure	Attitude of bedding		Axial plane	Fold axis	Inter-limb angle	Fold type
	North-eastern limb	South-western limb				
Gawan syncline	N42ºW/71ºSW	N29ºW/46ºNE	N36ºW/79ºNE	14º/138º	63º	Open
Gawan antincline	N29ºW/46ºNE	N58ºW/60ºNE	N50ºW/82ºNE	22º/129º	74˚	Open
Mandi syncline	N58ºW/80ºNE	N38ºW/49ºNE	N50ºW/65ºE	26˚/132˚	31˚	Close
Sarda-Sarhota Syncline	N27ºW/60ºSW	N20ºW/85ºNE	N22ºW/76ºSW	06º/158º	35º	Close
Fagosh annticline	N45°W/85°NE	N33°W/55°SW	N39°W/89°SW	20°/320°	40˚	Close

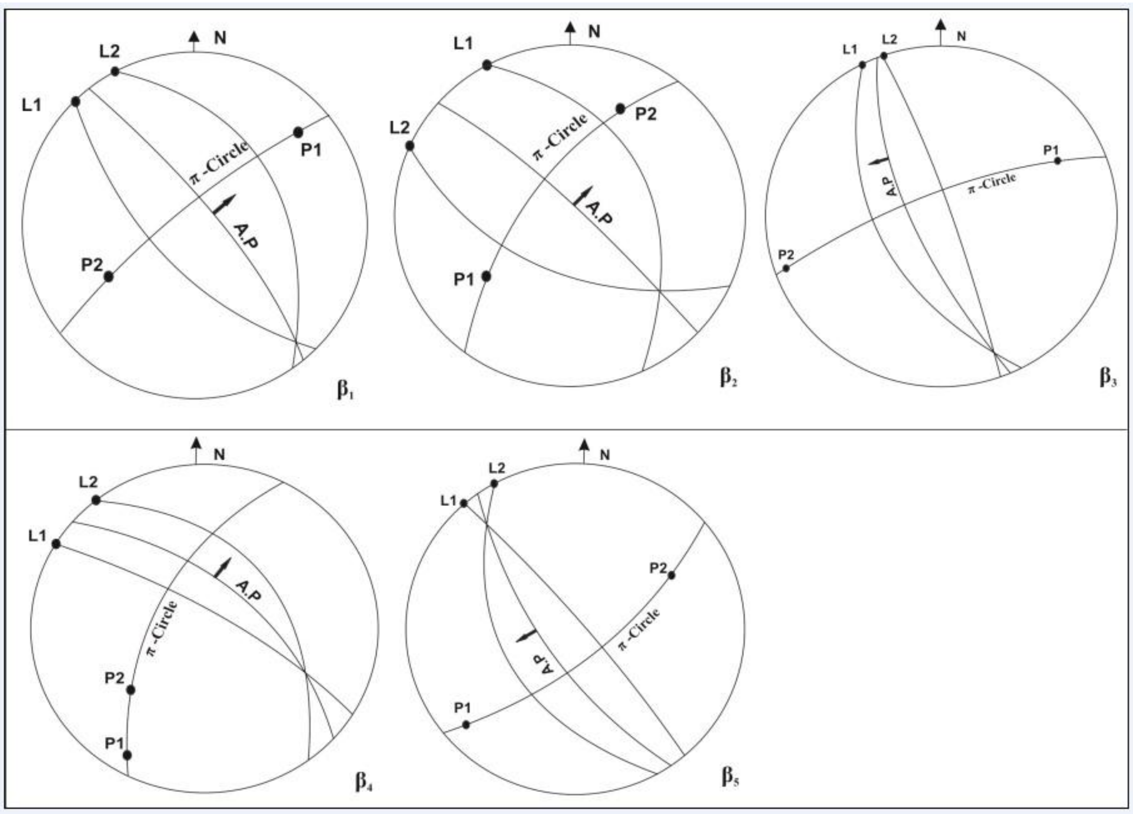

Figure 5. The π and β diagrams of Gawan anticline- β1,β2, Sarda-Sarhota syncline- β3, Mandi syncline- β4, and Fagosh anticline-β5.

which is passing through the core of anticline as shown in cross section FF′ (Figure 3). The strike of the southwestern limb is N33˚W whereas the strike of the northeastern limb is N45˚W. The dip of the southwestern limb is 55˚SW whereas the dip of the northeastern limb is 85˚NE. Attitude of the axial plane is N39˚W (Table 2; Figure 5, β_5). The interlimb angle is 40˚ which shows that the Fagosh anticline is a close fold.

3.7 *Faults*

In the study area, two faults are present which are Riasi Fault and Fagosh Fault. The faults are mostly thrust faults and their fault planes are northeast dipping. Fault controlled gullies and topographic fronts are present.

3.8 Riasi Fault

The Riasi Fault is also known as The Kashmir Boundary Thrust (KBT). The Riasi Fault is the major fault which passes through the project area (Baig and Lawrence, 1987). In the study area it runs through Kartot, Sarhota, Dasia, Bani Nagala and Kingrian. It extends in northwest-southeast direction towards Jammu. The Riasi Fault thrusted Murree Formation over the Dhok Pathan and Soan Formations. The Murree Formation lies in the hanging wall of the fault while the Dhok Pathan and Soan Formations lie in the foot wall of the Riasi fault as shown in cross Sections BB′, CC′, DD′, EE′ (Figure 4). The attitude of the fault plane at Bani Nagala is N80˚W/63˚NE. The attitude of hanging wall and foot wall blocks is N55˚W/88˚NE and N64˚W/43˚NE respectively. The Riasi fault has truncated the northeastern limb of the Mandi syncline. The fault zone is exposed in the project area along nalas and roadsides where shearing crushing and gouge are present.

3.9 Fagosh Fault

The Fagosh Fault is an intraformational fault which lies within the Chinji Formation. The fault is developed in the core of Fagosh anticline due to the strong tectonic activities. The fault is well exposed at Dheri along the roadside. The fault extends in the northwest-southeast direction as shown in Cross Section FF′ (Figure 4). The Chinji Formation is exposed both in the foot wall and the hanging wall. The attitude of bedding in the hanging wall and foot wall is N19˚W/81˚SW and N49˚W/85˚NE respectively. The attitude of fault plane is N30˚W/65˚NE. The shearing and crushing is present in the core of the Fagosh anticline where the fault plane is well exposed (Figure 4).

4. Conclusion

Based on above discussion, following conclusions are made:

a. The project area lies along the eastern limb of the Hazara-Kashmir Syntaxis in the sub-Himalaya of Pakistan which is developed after the Tertiary collision of the Indian and Eurasian Plates [13].

b. The sedimentary rocks are exposed in the area range in age from Miocene to Recent. These are the molasse deposits formed by the accumulation of eroded stuff carried by fluvial systems from higher Himalayan domain to the marginal zone in Kashmir Basin.

c. The area is highly deformed into large scale folds and faults due to stresses produced by the tectonic activities. The major folds of the area are the Gawan syncline, Gawan anticline, Sarda-Sarhota syncline, Mandi syncline and Fagosh anticline. These folds are northwest-southeast trending, northeast or southwest verging, open to close and northwest or southeast plunging. The Gawan syncline is formed by the folding of the Paleocene-Eocene rocks and Murree Formation sharing the northeastern limb of the Gawan anticline. The Gawan anticline is formed due to the folding of Kuldana Formation and Murree formation. The Kuldana Formation is present in the core of the fold. The Sarda-Sarhota syncline is formed due to the folding of Murree Formation. The Mandi syncline is formed due to the folding of Siwalik Group of rocks. The Soan Formation is found in the core of the syncline whereas the Dhok Pathan and Nagri Formation lie in the northeastern and southwestern limbs of the syncline. The Fagosh anticline is a faulted anticline formed due to the folding of the Chinji and Nagri Formation. The Chinji Formation lies in the core and the Nagri Formation lies at the limbs of the anticline.

d. The major faults found in the area are the Riasi Fault and the Fagosh Fault. The Riasi Fault is the major fault passing through the project area. The Riasi fault is marked between the Murree Formation and Siwalik Group of rocks. The Murree Formation lies in the hanging wall and the Dhok Pathan and Soan Formations in the foot wall of the Riasi Fault. The Fagosh fault is an intraformational fault which lies within the Chinji Formation. The Fagosh Fault is present in the core of the Fagosh anticline at Dheri along road side.

e. The primary sedimentary structures like load casts, ripple marks and cross bedding are present in the study area. The facing of the different rock units is marked on the basis of these sedimentary structures.

f. Based on above findings, a detailed geological and structural mapping of the area is recommended for the economic evaluation of the HKS and adjoining area.

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